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Reflections on the Geoacoustic and Geotechnical Characteristics of Eckernförde Bay Sediments

Kenneth S. Davis, William B. Bryant, Niall C. Slowey, and Douglas N. Lambert

Sediments on the floor of Eckernförde Bay were collected in gravity cores during two cruises in the early spring of 1993 for an investigation of sediment geoacoustic and geotechnical properties. Compressional wave velocities and sediment bulk densities were measured at 1 cm intervals using a multi-sensor core logger. Water contents were measured using standard methods. High-resolution, vertical-incidence seismic profiles of the seafloor were collected using the Naval Research Laboratory's Acoustic Seafloor Classification System (ASCS) at the same locations as the sediment cores. These data allow an examination of sediment property variations and their expression on the seismic profiles.

Preliminary results for 2-m long gravity cores indicate that measured compressional wave velocities in gas-free regions of the seafloor range from ~1480 to 1580 m/s - typical of soft, fine-grained marine sediments (Figure 1). In gassy areas, velocity decreases sharply at the depth where free gas is present; measured velocities in gassy sediments range from ~900 to 1200 m/s (Figure 1). Seismic profiles of the seafloor at the locations where gassy cores were collected display a prominent reflector at the same depth where the sharp decrease in velocity occurs (Figure 2).

Density profiles of non-gassy sediments show relatively more variability than corresponding velocity profiles. Typically, a density profile shows a slight decrease in the upper portion of the core, than either increases or remains constant to the base of core (Figure 3). The average bulk density of sediments at the top of the cores is ~1.5 g/cm^3 and the range of density values throughout the cores is 1.36 to 1.82 g/cm^3.

The water content profile for core BSGC-008 shows an increase in the upper 100 cm of the core, then abruptly decreases from 100 to 200 cm, and then remains fairly constant to the base of core (Figure 4). Likewise, changes in lithology (i.e., the presence of gas fractures) also occur at 100 cm and 200 cm intervals (Figure 5). Though velocity and density values could not be measured using the multi-sensor core logger, it is reasonable to presume that changes un these properties, and so acoustic impedance, occur at the same depths as changes in the water content and lithology. The ASCS profile through the site of this core supports this hypothesis. Two prominent reflecting horizons occur at 100 cm and 200 cm, which are consistent with the presence of gas in the sediment.

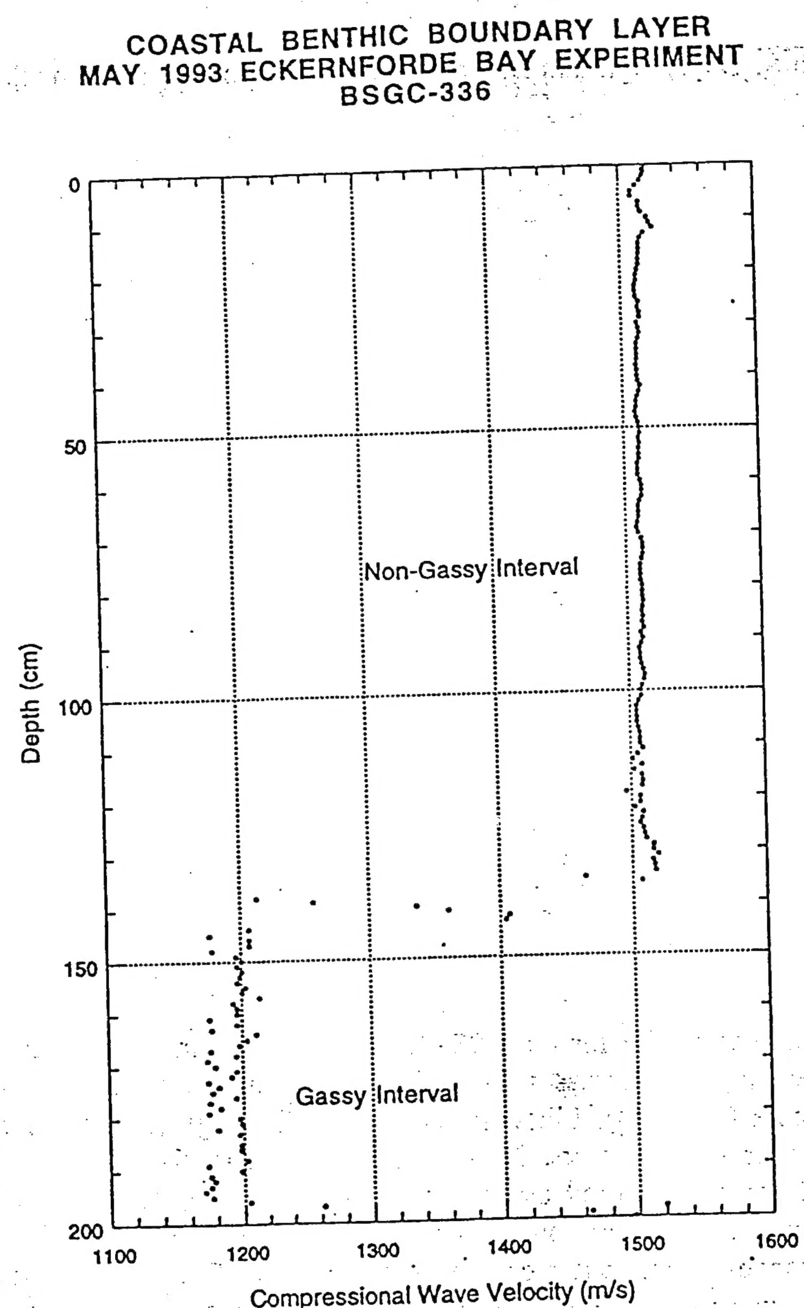

Figure 1: Velocity profile for gravity core BSGC-336. This profile illustrates typical compressional wave velocities for non-gassy sediments (upper 135 cm) and gassy sediments (135 cm to base of core).

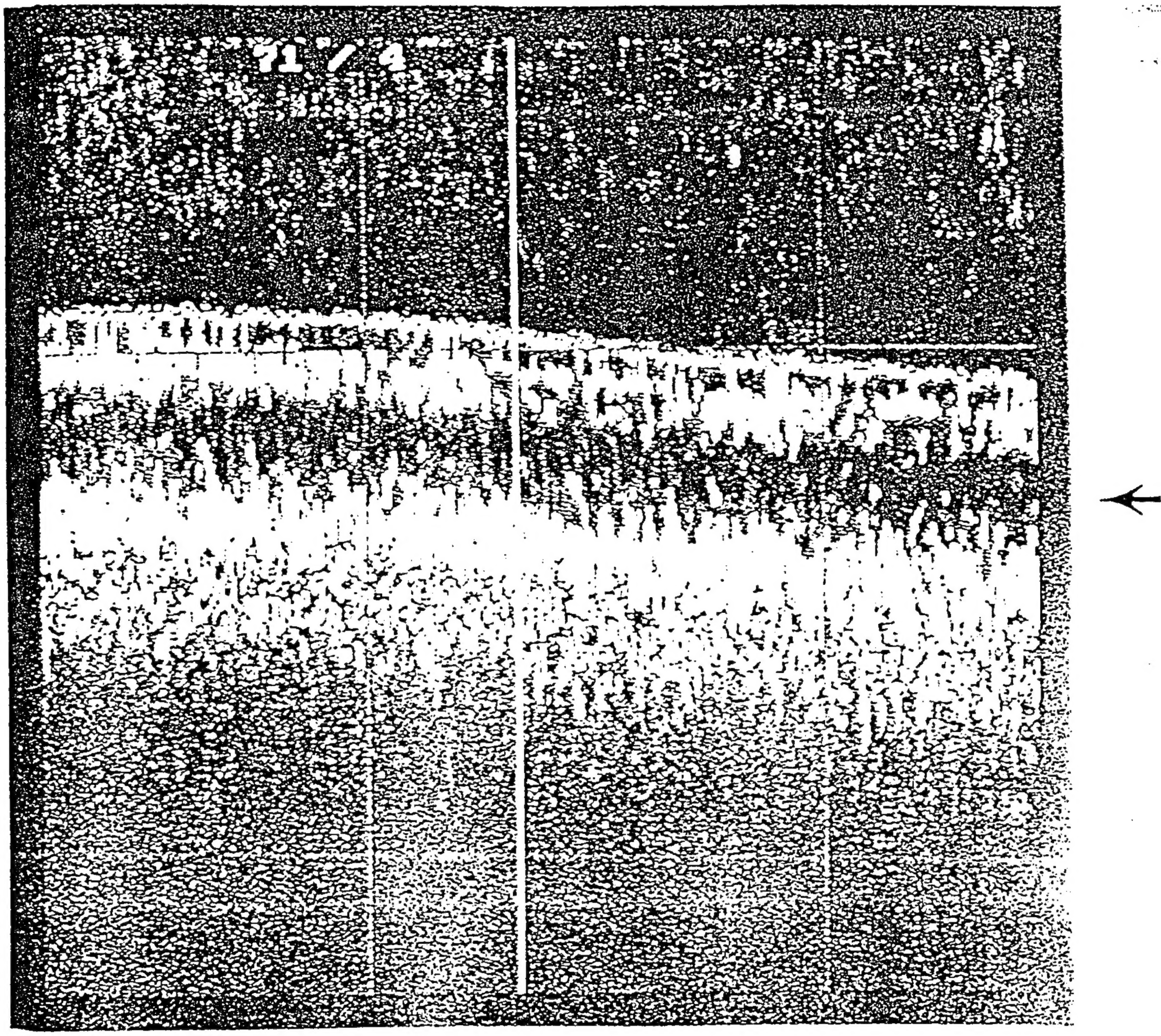

Figure 2: Acoustic Seafloor Classification System (ASCS) profile acquired in a gassy region of Eckernförde Bay. The arrow is pointing to a prominent reflector approximately one meter below the seafloor that is interpreted as representing gassy sediment.

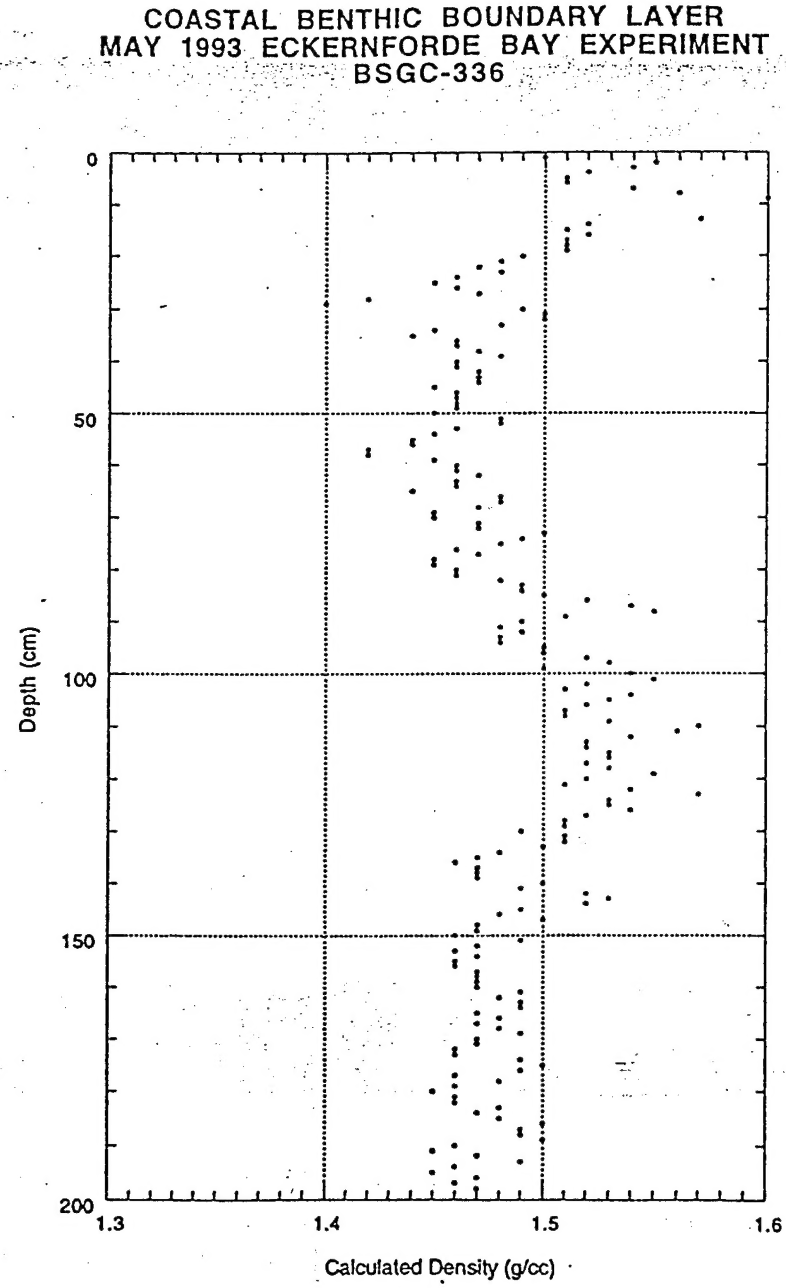

Figure 3: Density profile for gravity core BSGC-336. Changes in density display more down-core variability than does the velocity profile in this core (Figure 1). Note that density changes occur in the non-gassy interval (0-135 cm) and remains constant in the gassy interval (135 cm to base of core).

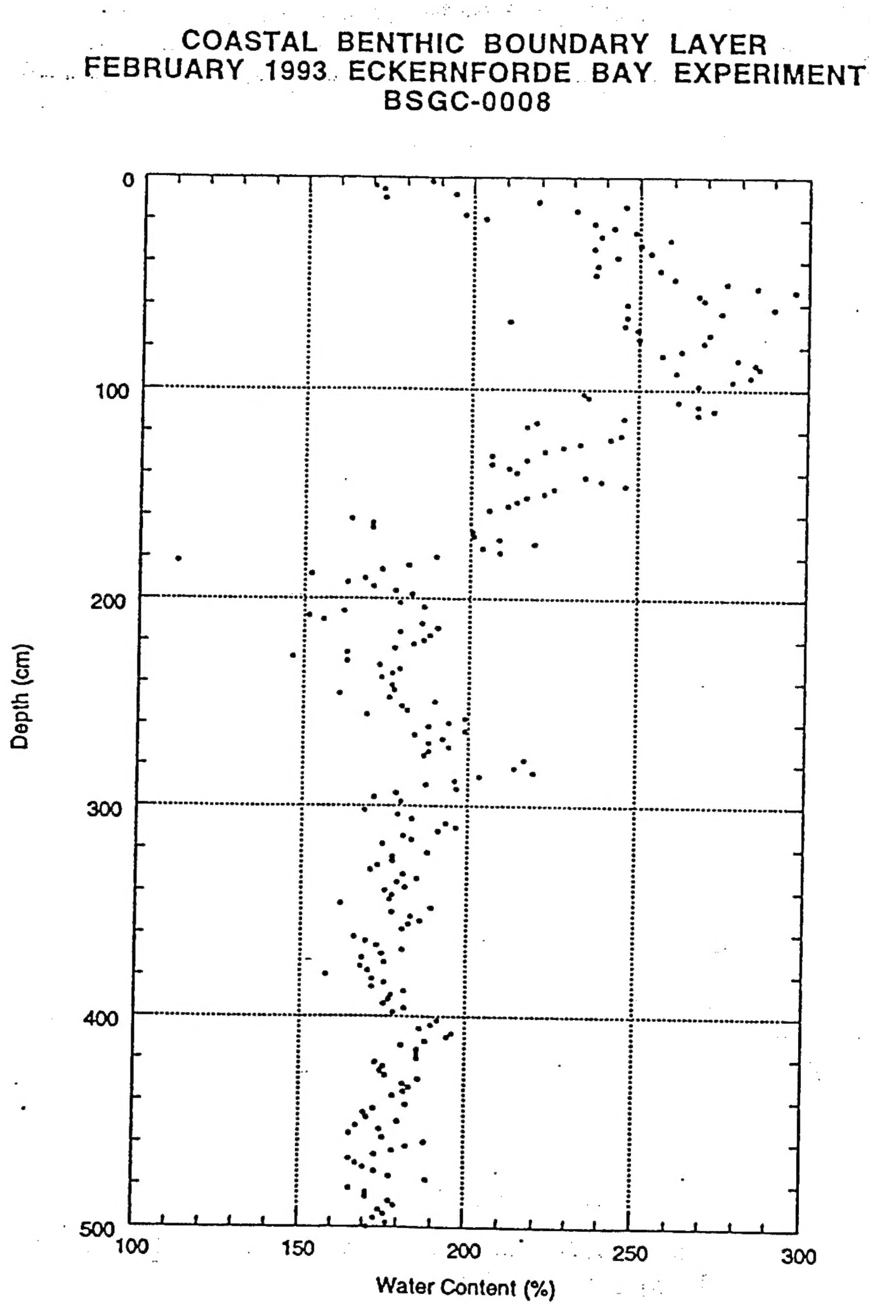

Figure 4: Water content profile for 5-meter long gravity core BSGC-0008. Notice that changes in water content occur at 100 cm and 200 cm, below which it remains essentially constant. It is interesting to compare this figure with Figure 5.

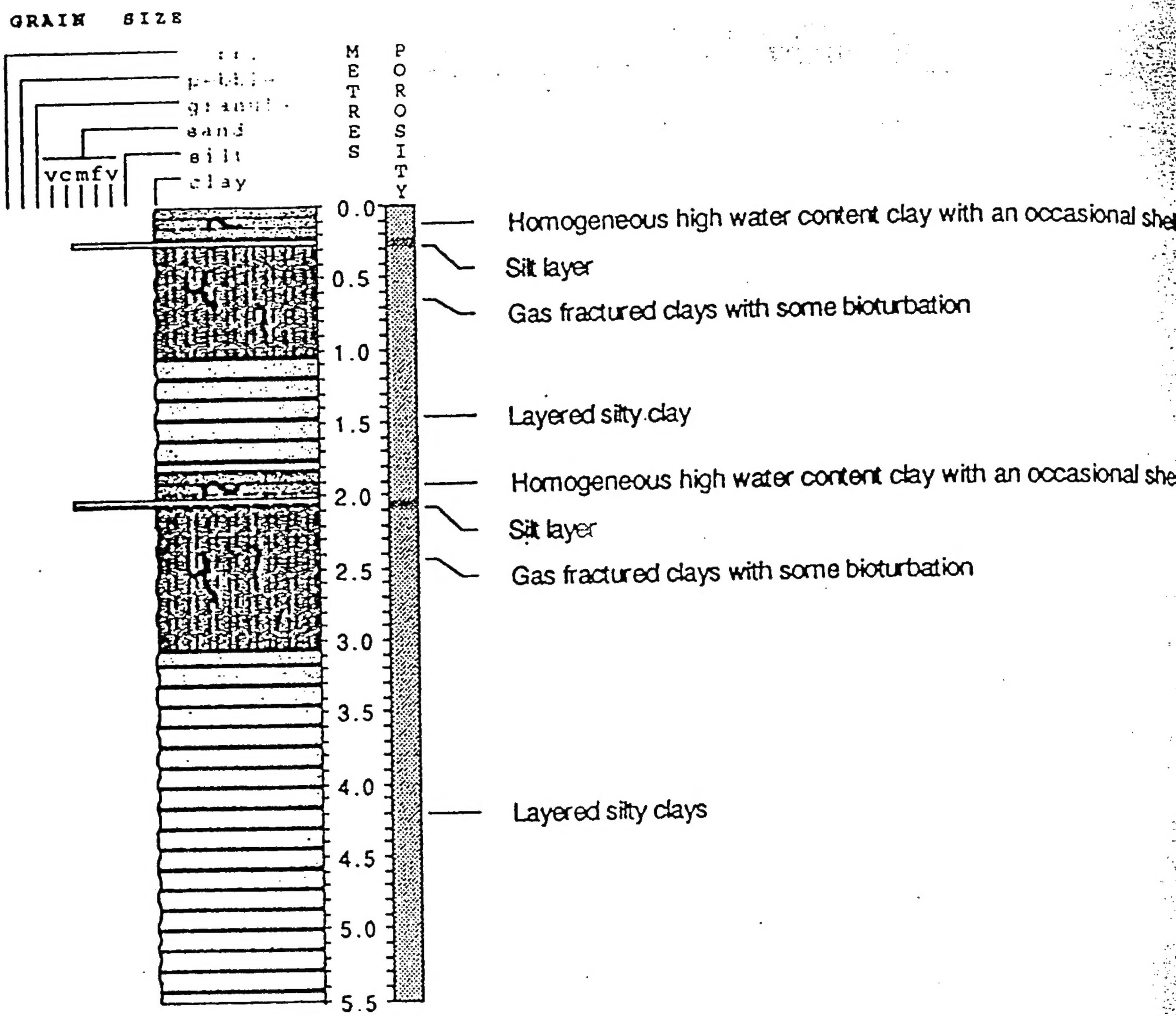

Figure 5: This figure illustrates the lithology of 5-meter core BSGC-0008. Note that changes in lithology occur at the same position as changes in water content (100 cm and 200 cm) shown in Figure 4.

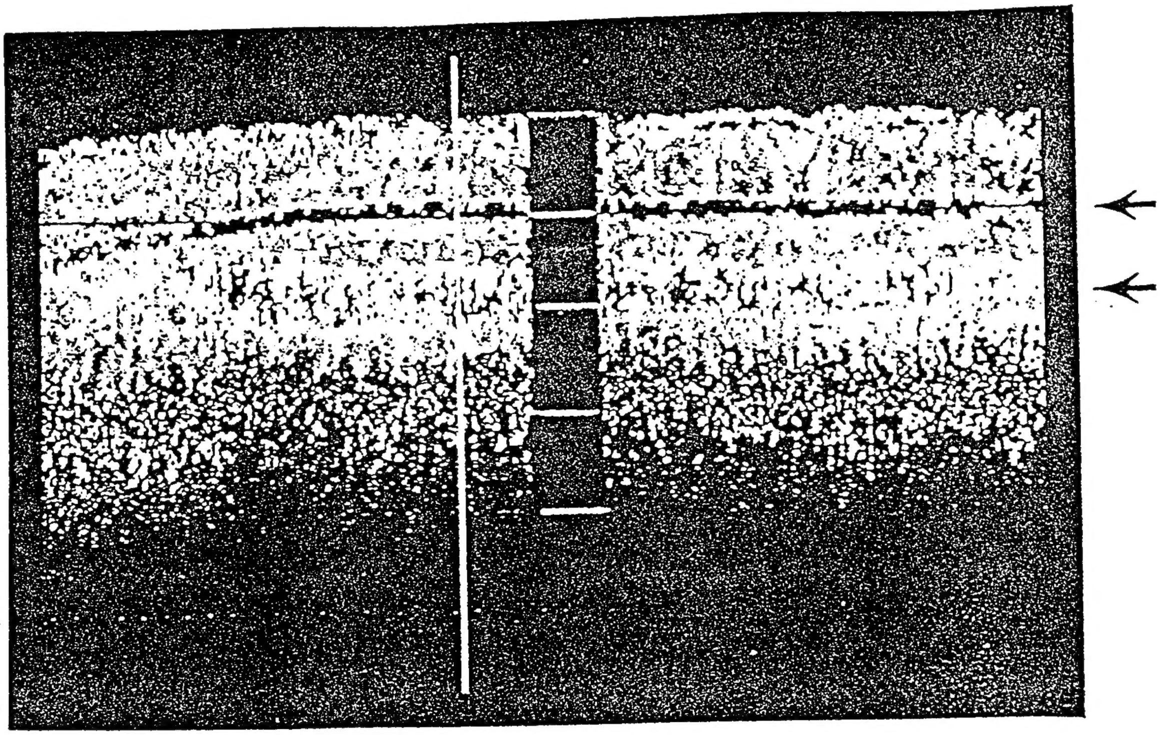

Figure 6: Acoustic Seafloor Classification System (ASCS) profile acquired in the same area where BSGC-0008 was collected. The seismic profile suggests two gas horizons occurring at 100 and 200 cm below the seafloor. The physical properties and lithology of BSGC-0008 indicate the presence of gas. The arrows point to the prominent reflectors 100 cm and 200 cm below the seafloor, consistent with our interpretation of changes in water content and lithology.

Acoustic Imaging of Near-Surface Bubbly Sediments

Jim A. Hawkins, Douglas N. Lambert, Don J. Walter, and John C. Cranford

Using a high resolution Acoustic Sediment Classification System (ASCS), we have investigated bubble fields occurring in near-surface sediments in several areas from the western Baltic Sea in Eckernförde and Kiel Bays, and off the Mississippi coast of the Gulf of Mexico. In this paper, we will present seismic records taken in these areas illustrating typical features of the bubble fields. Figure 1 is a record taken in the 'pock mark' area of Eckernförde Bay which shows a very dynamic bubble layer. The intensity of the reflected signal is shown by color (6 dB/color): hot colors indicate high reflectivity, cool colors indicate low reflectivity. The bubble layer spans the entire record except at the edges of the pock mark. At each edge the bubble layer disappears revealing a previously hidden sublayer. It is speculated that out-gassing periodically occurs near these edges leaving the sediment essentially gas-free.

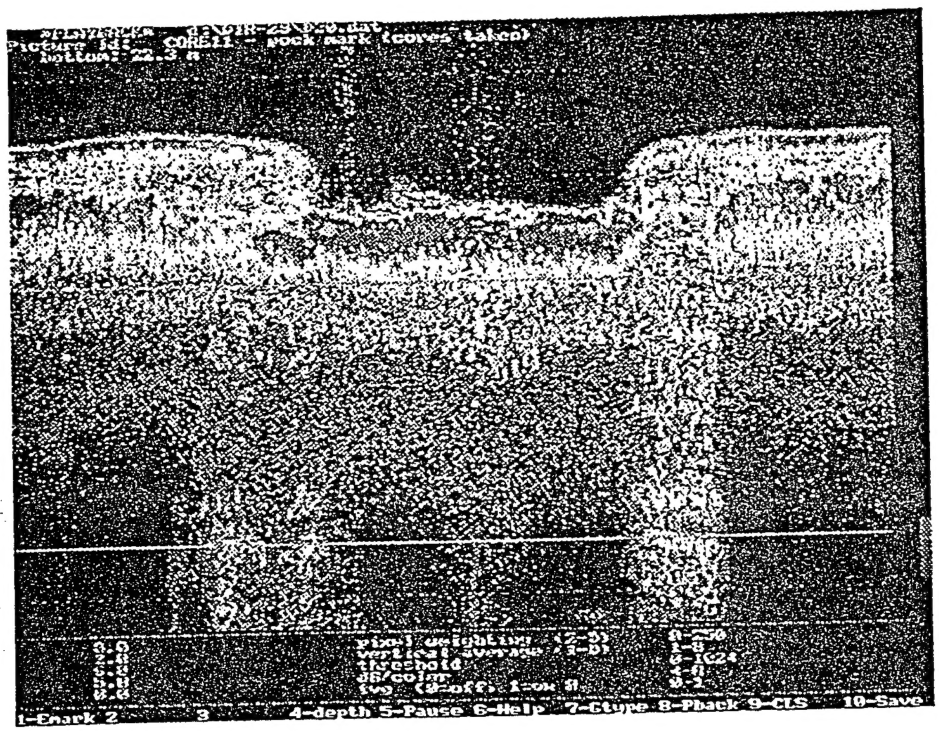

Figure 1: ASCS display of a 'pock mark' found in Eckernförde Bay. Note the layer of bubbles lying about 1 m below the surface and the relatively bubble free region near the edges of the pock mark where a sublayer can be seen about 5 meters deep.

In Figure 2, we show another seismic record from Eckernförde Bay in the area of the joint CBBL/JOBEX experiment region. The prominent red layer (again high reflectivity is indicated by the bright red region) lying about 0.75 m to 1.0 m below the sediment sur

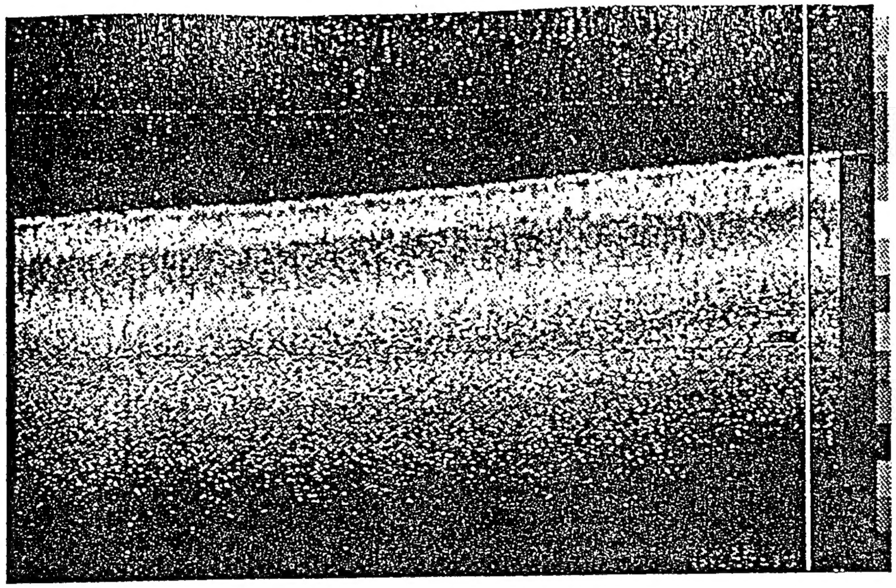

Figure 2: ASCS subbottom seismic profile of sediments in the CBBL/JOBEX experiment area, Eckernförde Bay, SW Baltic Sea. A biogenic gas horizon is shown at about 1 m below the sediment water interface.

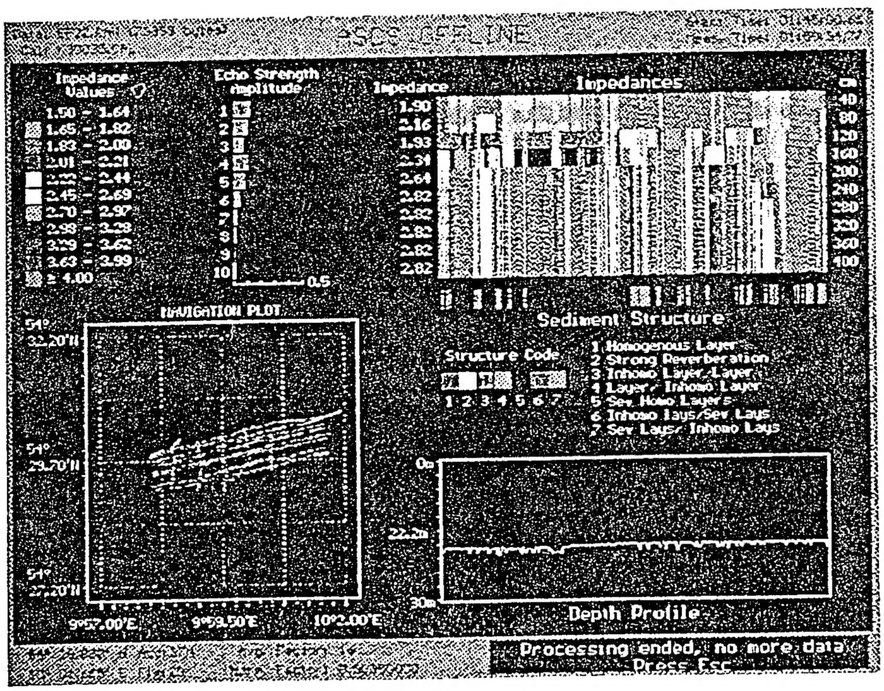

Figure 3: Color display of the ASCS sediment characterization program showing the impedance (upper right) measured along track lines (lower left) in the CBBL/JOBEX test.

face and approximately a meter thick is believed to be part of a large bubble field existing throughout the test area. With the ASCS system, we are able to characterize the geo-

acoustic properties of the sub-bottom. In Figure 3, we show a typical window from the ASCS sediment classification program. Among the data shown in this window are the GPS navigation lines and a scrolling display of the impedance as a function of depth.

Using the impedance profiles collected for the entire region, we can construct a 2-D map of interpolated impedance values for the entire test area (Figure 4 shows a portion of the area). In Figure 4 (note that the colormap is different than the ASCS display), we see that the bubble field (indicated by the light blue to red areas) is prominent in this part of the test area. In fact, we have found that the bubble field extends throughout the test area.

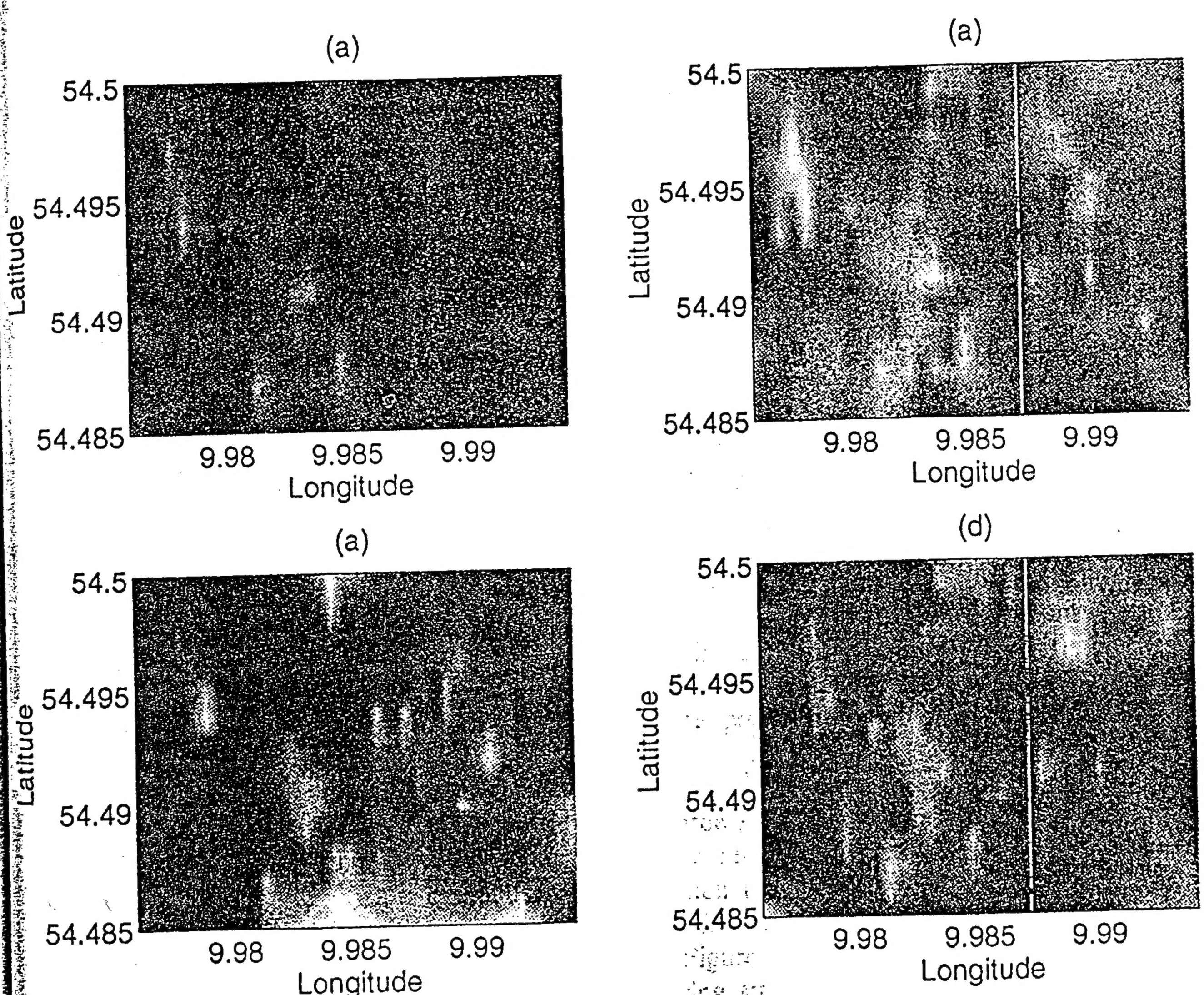

Figure 4: The ASCS interpolated impedance values from the CBBL/JOBEX test site for the surface (a) and three sublayers: (B) 40-80 cm, (c) 80-120 cm, and (d) 120-160 cm. Note the relatively high impedance associated with the presence of bubbles (light blue to yellow) of the sublayers compared to the bubble-free surficial impedance (dark blue). (Note that the colormap differs somewhat from previous figures).

Figure 5 (from the Baltic) and Figure 6 (from the Mississippi Gulf Coast) show remarkably detailed pictures of bubbly sediments. First, Figure 5 shows a bubble field which appears to be percolating upward. Figure 6 shows multiple sub-layers that are thought to be bubbles located along bedding planes. Conventional continuum theory of sediments suggests that the presence of bubbles should greatly inhibit acoustic systems. For example, bubble resonance effects should cause complete reflection of incident sound waves. In fact, in many cases bubbles can limit subbottom penetration of the ASCS. This contrasts with the detailed images of bubbles obtained by the ASCS. It is thought that in some regimes where the sediments are characterized by impedances close to that of water and the source frequencies are high compared to the bubble resonance frequency, bubbly sediments can be treated as an acoustic medium containing discrete scatterers (bubbles).

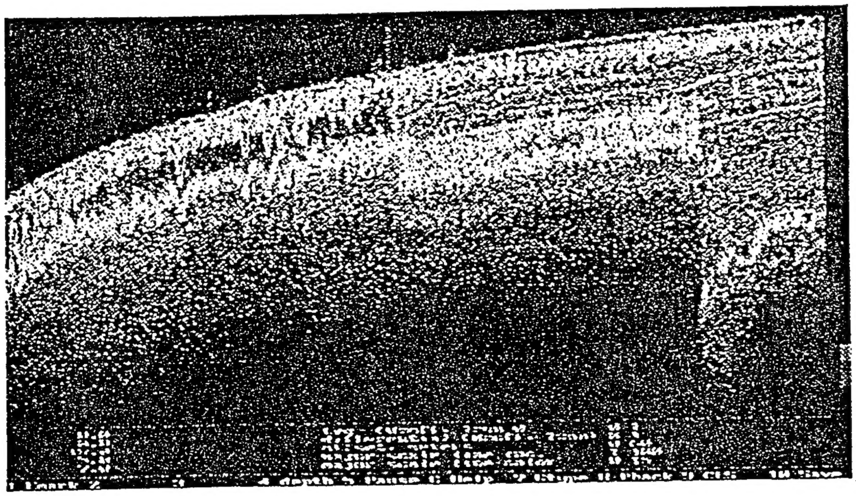

Figure 5: Example of a 30 kHz ASCS seismic profile from the western Baltic Sea. In this record, the yellow and red areas represent concentrations of biogenic gas, probably methane. This sediment is a soft clay fairly rich in organic matter. Note how the gas in the sediment appears to have a vertical orientation which suggests some percolation motion of the bubbles.

This situation appears to be the case in Eckernförde Bay. The question is how to acoustically characterize the physical properties of the sediment. Most classification systems (including the ASCS) are based on the assumption of multiple homogeneous layers. In areas like Eckernförde Bay a scheme for acoustic characterization based on scattering theory seems more appropriate. For example, Figure 7 (provided by Aubrey Anderson and Tony Lyons), shows the comparative scattering strengths of a distribution of bubbles and a continuum with high and low variance. The scattering strength of the bubbles is roughly 30 to 40 dB higher. If we look at Figure 2, the low intensity areas are at least 30 dB lower than the bubble region. This results is in qualitative agreement with Figure 7.

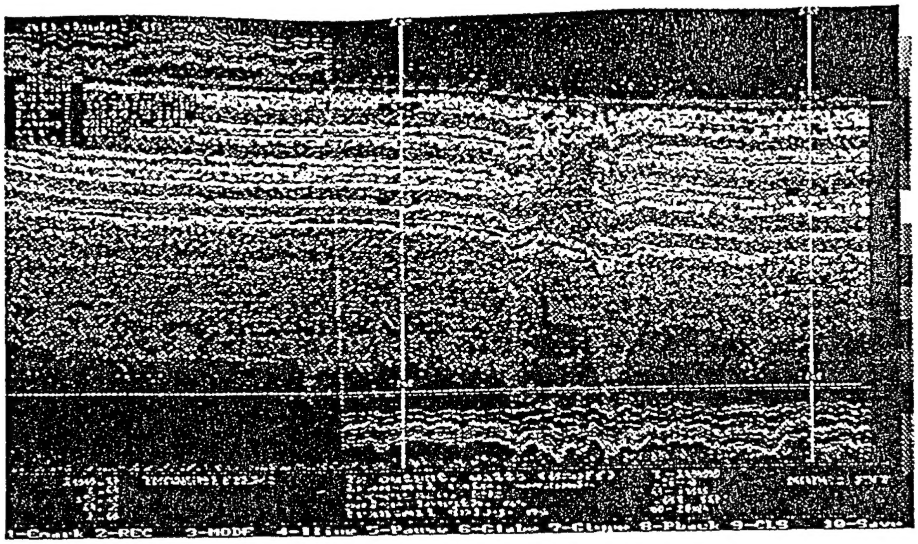

Figure 6: Example of a 15 kHz ASCS seismic profile from the Gulf of Maxico southeast of Ship Island. In this picture, the yellow and red layers are thought to be minor concentrations of biogenic gas, probably methane, lying along horizontal bedding planes in the sediment column. This sediment is a soft silty clay fairly rich in organic matter and cores previously taken in the area do not indicate the presence of sand lenses that would be reflective enough to produce the strong layered returns seen here.

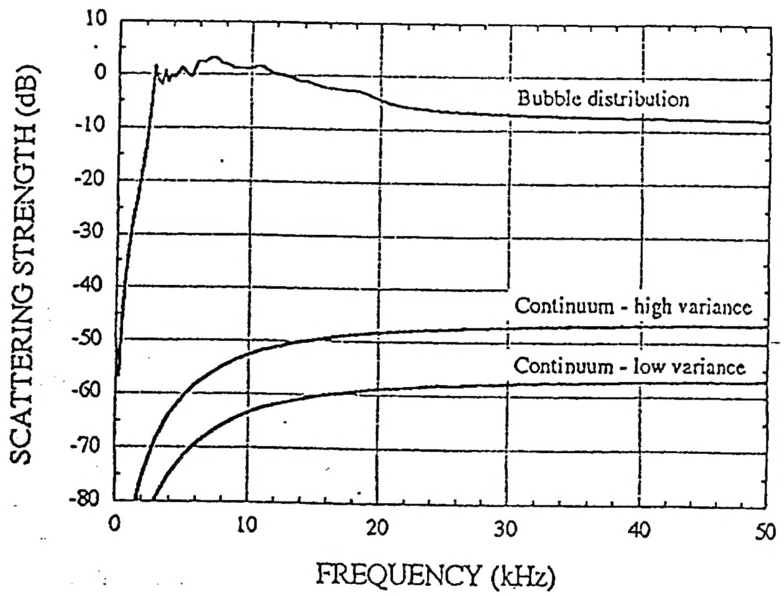

Figure 7: Backscattering strength predictions bysed on sediment properties consistent with those measured in Eckernförde Bay. The comparison is made between backscatter strength of a bubble field with a distribution of bubble sizes (upper curve) and the backscatter from a two continuum, one with high variance and one with low variance (lower two curves). Note that the backscatter strength of the bubble diftribution is higher by more than 30 dB. (Figure provided by Aubrey Anderson and Tony Lyons).

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Sediments on the floor of Eckernförde Bay were collected in gravity cores during two cruises in the early spring of 1993 for an investigation of sediment geoacoustic and geotechnical properties. Compressional wave velocities and sediment bulk densities were measured at 1 cm intervals using multi-sensor core logger. Water contents were measured using standard methods. High-resolution, vertical-incidence seismic profiles of the seafloor were collected using the Naval Research Laboratory's Acoustic Seafloor Classification System (ASCS) at the same locations as the sediment cores. These data allow an examination of sediment property variations and their expression on the seismic profiles.

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